Investigation

# AUTOMOTIVE EMISSIONS AND THE GREENHOUSE EFFECT

## Background Information

*The Background This background was adapted from a feature article by Charles Kutscher that appeared in the July/August 2006 issue of SOLAR TODAY magazine.*

Since the early 1800's we have known that various atmospheric gases, acting like the glass in a greenhouse, transmit incoming sunlight but absorb outgoing infrared radiation, thus raising the average air temperature at the Earth's surface.

Carbon dioxide, a major byproduct of fossil fuel combustion, is clearly the most influential greenhouse gas.

Data shows that over the past 420,000 years, the CO2 content in the atmosphere has varied cyclically with a period of about 100,000 years (in conjunction with variations in the Earth's orbit) between a minimum value of about 180 parts per million (ppm) by volume and a maximum of about 290 ppm.

Around 1850, when the CO2 level was still sitting at about 280 ppm, or near the top of a very gradual geological cycle, the level began to shoot upward. It has now reached the unprecedented value of 380 ppm—a 36% increase over the pre-industrial value and is rising at the incredible rate of about 2 ppm per year.

It is clear, however, that an exploding population of human beings who are burning more and more fossil fuel now has a greater effect on the climate than natural mechanisms. We are now the major determinant of the climate of our planet. The atmosphere can no longer be viewed as an infinite sink into which we can dump our wastes.

In the U.S. the burning of fossil fuels results in the emission of 1.6 billion tons of carbon per year in the form of carbon dioxide. This represents 23% of the world's total CO2 emissions—a large proportion considering that we have only 5% of the world's population. Electricity production accounts for 42% of our total carbon emissions and the burning of transportation fuels accounts for 32%, so targeting electricity generation and transportation fuels will address about three-quarters of our CO2 emissions.

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In this investigation you will compare the amount of Carbon Dioxide (CO2) in four different sources of gases and determine the CO2 contribution from automobiles.

## Problem *(fill in problem):* ____________________________________________

____________________________________________________________

## Hypothesis

If ____________________________________________________________

Then____________________________________________________________

## Materials

5 vials or test tubes
A graduated cylinder
A funnel straw A marble-size piece of modeling clay
4 different colored balloons
4 twist-ties A narrow-necked bottle (the neck should be narrow enough for a balloon to fit over it)
A dropping bottle of bromthymol blue indicator solution
A dropping bottle of dilute household ammonia (1 part ammonia to 50 parts distilled water)
100 mL vinegar
5 mL baking soda
Safety goggles for wear at all times

## Procedure

1. Add 15 mL of water and 10 drops of bromthymol blue indicator solution to each vial or test tube. Label the vials A, B, C, D, and Control.

2. Fill each balloon until it has a 7.5 diameter.
   **Sample A (Ambient Air)** - Use a tire pump to inflate the balloon to the required diameter. Twist the rubber neck of the balloon and fasten it shut with a twist tie. The tie should be at least 1 cm from the opening of the balloon. Record the color of the balloon used for this sample.
   **Sample B (Human Exhalation)** - Have one team member blow up a balloon to the required diameter. Twist and tie the balloon, and record balloon color.
   **Sample C (Automobile Exhaust)** - Your teacher will supply you with this balloon. Record the color.

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**NOTE:** When collecting the exhaust you should wear thick gloves to protect your hands from being burned. Fill the balloons in an open area and when a slight breeze is blowing to keep the exhaust gases away from your face. Place a balloon over the narrow end of a metal funnel and place the wide end of the funnel over the exhaust pipe of a running car. When inflated, the balloons should be about 7.5 cm in diameter. It may be easier to over inflate the balloon and then let a little gas escape. Twist and tie the balloon. You will need one balloon filled with exhaust for each lab group.

**Sample D (Nearly pure CO2)** - Put 100 mL of vinegar in the narrow-necked bottle. Using a funnel, add 5 mL of baking soda. Let the mixture bubble for 3 seconds to drive the air out, then slip the balloon over the neck of the bottle. Inflate the balloon to the proper diameter. Twist, tie, and record the color.

3. Soften the clay and wrap it around one end of the straw to make a small airtight collar that will fit into the neck of a balloon. The collar should look like a cone with the straw in its middle, and should be large enough to plug the neck of the balloon.

4. Pick up Balloon A. Keeping the tie on it, slip the balloon's neck over the clay collar and hold it against the collar to make an airtight seal. Place the other end of the straw into the vial of water and bromthymol blue labeled A. Have another partner remove the tie on the balloon and slowly untwist the balloon. Keeping the neck of the balloon pinched to control the flow of gas, gently squeeze the balloon so the gas slowly bubbles through the solution.

5. Repeat the same procedure with the other balloons and their respective vials. In some cases, the bromthymol blue solution will change color, from blue to yellow, indicating the presence of carbonic acid formed from CO2.

6. Analyze each of the samples by titrating them with drops of dilute ammonia. Ammonia neutralizes the carbonic acid. The bromthymol blue will return to a blue color when all the acid has reacted. Add drops of ammonia to each of the samples that turned yellow, carefully counting the number of drops needed until they are about the same color as your control. Record the results.

# Observations

1. Which samples indicated the presences of carbonic acid, which forms from CO2? ________________

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2. How many drops of ammonia were required to turn each sample the same color as your control? ___

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## Conclusion

1. Which samples had the most and the least carbon dioxide? ______________________________

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2. Why didn't the ambient air sample turn yellow? ______________________________

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3. Why is automobile exhaust a concern? ______________________________

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## Application

Calculate the amount of $CO_2$ created by the automobiles in your family by filling in the table below.

| Question | How to Calculate | Car 1 | Car 2 | Car 3 |
|---|---|---|---|---|
| How many miles per gallon (MPG) does your car get? | Fill the gas tank and record odometer reading. At the next fill-up, record number of gallons of gas added and divide by number of miles driven since previous fill-up | (MPG) | (MPG) | (MPG) |
| What are the $CO_2$ emissions per mile (EPM) for your automobile? | EPM = 20 lbs./MPG | (EPM) | (EPM) | (EPM) |
| Ho many daily miles (DM) do you drive? | For each automobile, on a typical day, record the odometer reading in | (DM) | (DM) | (DM) |

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| | | | | |
|---|---|---|---|---|
| | morning and again at the end of the day. Subtract to get the number of miles driven | | | |
| What are the daily emissions (DE) of CO2 for your automobile(s) | DE = EPM x DM | (DE) | (DE) | (DE) |
| How many annual miles (AM) do you drive? | AM = DM x 365 | (AM) | (AM) | (AM) |
| What are the annual emissions (AE) of CO2? | AE = EPM x AM | (AE) | (AE) | (AE) |
| | | | | |

4. What ways could you reduce the amout of CO2 you create? ______________________________

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5. How could a city reduce the amount of CO2 they emit? ______________________________

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6. What's more important, to develop and adapt cars with a new fuel that's safe for the environment or to improve public transportation systems? ______________________________

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7. What alternative power sources could be used with cars? ______________________________

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8. Why might it be difficult for the public to start using an alternative source? ________________

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*This activity is adapted from Bringing the Greenhouse Effect Down to Earth, published by the Climate Protection Institute and the Global Systems Science (GSS) project at Lawrence Hall of Science, University of California, Berkeley. To receive more information about GSS and other activities visit www.lawrencehallofscience.org/gss. This activity originally appeared in The Science Teacher, May 1989.*